Analyzing Performance of File Aggregation in VELOC

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The Need for Aggregation

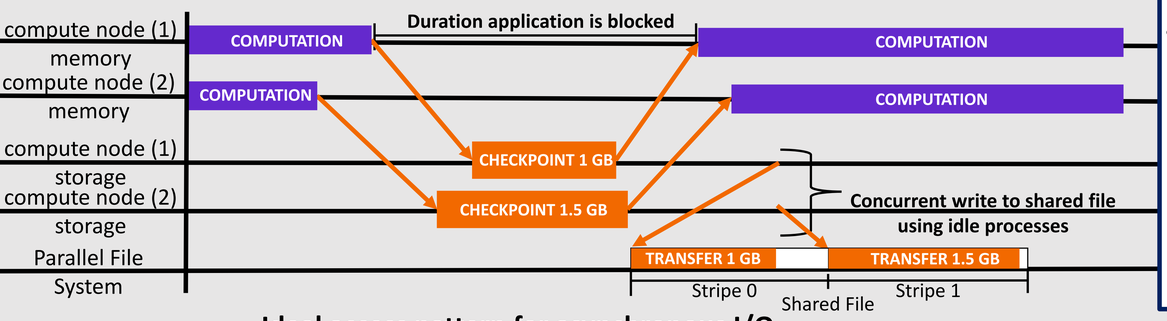
- Synchronous checkpointing methods (e.g. GenericIO) are projected to be infeasible at Exascale
- Asynchronous multi-level checkpoint runtimes like VELOC leverage fast local storage and flush to a parallel file system (PFS) independently in the background
- VELOC uses a one-file-per-process write strategy leading to I/O contention and many files on the PFS in applications that utilize large numbers of processes
- **We implement 2 working prototypes for asynchronous aggregation: (1) POSIX-based and (2)MPI-IO collective routine**
- **Study the behavior of said aggregation implementations on asynchronous checkpointing**
- **Compare results to VELOC's file-per-process asynchronous strategy, and GenericIO's synchronous aggregation strategy**

Approach

- Each process participating in checkpoint obtains offset in shared file using **Parallel Prefix-Sum**
- **POSIX-based**: baseline for asynchronous aggregation by **not** using any I/O optimizations

  Mmap local file to memory → open remote file lseek to offset → write
- **Ideal asynchronous aggregated workflow:** block application only for time it takes to checkpoint locally, eliminate false sharing with stripe-aligned writes
- **MPI-IO based**: direct comparison to GenericIO since it uses collective MPI-IO operations. MPI-IO will internally exchange data between processes to coordinate access to PFS

  mmap local file to memory → collective open remote file → collective write-at offset

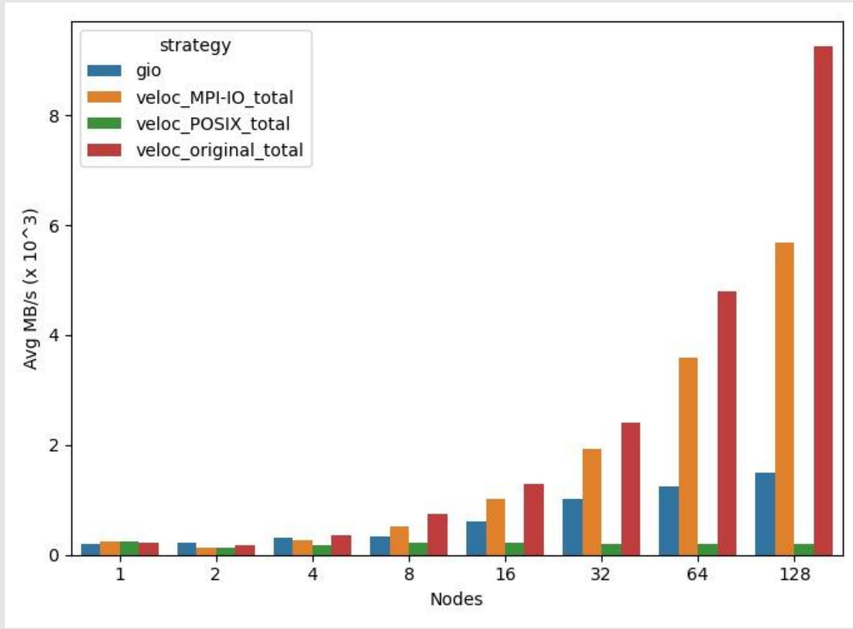


Ideal access pattern for asynchronous I/O

Experimental Setup

- All experiments are performed on Argonne© Theta, equipped with Intel Enterprise Edition Lustre PFS
- Microbenchmark spawns N (N = 1 → 128) processes, each checkpoints 1 GiB of memory
  - Top set of results number of nodes in varied
  - Bottom set of results number of processes per node is varied
- Stripe Size = 2 GB ; Storage Targets = min(N, 56), where 56 is the max available OSTs on Theta

Results

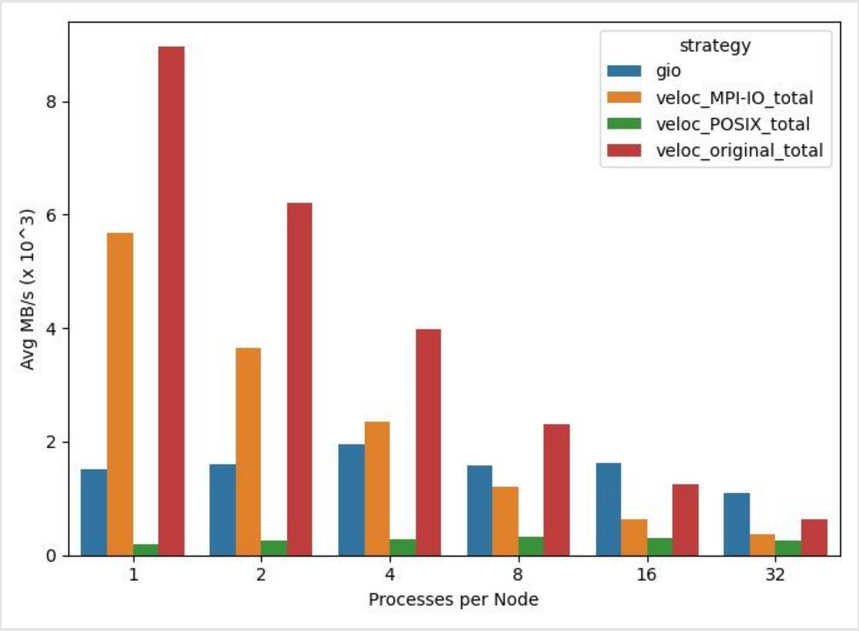


Bandwidth – 1 Process per Node:
With few numbers of processes per node less competition for local storage results in many flush requests at once :

- POSIX exhibits degraded performance since each process is accessing multiple OST's to copy their data at the offset
- MPI-IO maintains high throughput through data exchange and coordinated access

Bandwidth – Multiple Nodes & Processes
When more processes are added per each compute node:

- POSIX throughput improves slightly as processes on a node compete for local space, spreading out write requests to the PFS
- To avoid unnecessary synchronization due to the nature of collective MPI-IO calls the flushing mechanism on each compute node was altered to issue successive collective writes for each checkpoint file co-located on the node, thus serialization starts to overtake performance



Conclusions

- POSIX method suffers from congestion at the PFS level with few processes caused by false sharing and uncoordinated access patterns
- MPI-IO method suffers from multiple successive collective write calls for each node-local checkpoint, reducing chances for optimization
- In the future we will leverage the information from this preliminary study to design more sophisticated methods of aggregation that are optimized specifically for asynchronous, multi-level checkpointing

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